Innovations

Wastes into Wood: Composites Are a Promising New Resource

A comprehensive waste management program relies on the impact of several courses of action: waste reduction, recycling, waste-to-energy schemes, and landfilling. The greatest impact likely to result from further research is in the area of recycling. Increased use of recycled wood fiber will allow the markets for wood-based composites to grow without increasing the use of virgin timber. Forest products industries will benefit from such research because less expensive raw materials will be available for producing high-quality composites. As part of this effort, the Forest Products Laboratory of the USDA Forest Service has formed a multidisciplinary team of government, university, and industry specialists to work on this problem.

Wood Collection

The key to efficient wood and paper recycling starts with collection: wood and paper products must be properly separated to maximize efficiency. Recyclable wood may be in several different forms and comes from diverse sources. Dimensional lumber, which is made from softwoods, may be mixed with particle board. Pallets, which are usually made from hardwoods, may be mixed with tree trimmings. Paper products are also often mixed. Wood may be in the form of sawdust or large beams.

The cleanliness of used wood varies widely. Trimmings from new construction are usually clean, whereas wood from demolished buildings may be contaminated with lead-based paint. Nails, stones, plastic, gypsum, and concrete are typical contaminants of recyclable wood. In addition to these surface contaminants, wood may be impregnated with preservatives or fire retardants. Paper is commonly contaminated with staples, paper clips, ink, clay fillers, and other office products.

Composite Products

Recycling a material produces a new material that has a different position in the product hierarchy. For example, pallets can be chipped to make landscape mulch; magazines can be shredded to make animal bedding. In these examples, the new product has a lower position in the product hierarchy than the original product. Going down the hierarchy is easy, but fresh perspectives are needed when moving up the product hierarchy. One approach is to combine wood with dissimilar materials to make a wood composite, which has novel, beneficial properties.

Conventional wood composites. Conventional wood composites that are already on the market and have a high degree of customer acceptance include particleboard, fiberboard, and flakeboard. Many of these composites are made from recycled wood. A heat-curing adhesive holds the wood components together.

Particleboard used in furniture cores and shelving is derived from industrial planer shavings, a waste material from the manufacture of dimensional lumber and millwork. The planer shavings are hammermilled into small particles, coated with adhesive, and pressed under heat and pressure to make flat panels or molded shapes. Particleboard is typically covered with veneers or overlays to enhance its appearance. Because the wood particles have little or no fiber length, much of the strength of particleboard comes from the adhesive. As such, particleboard is typically not used for making structural applications. Most wood waste is suitable for making particleboard, including treated wood if adhesive systems can be developed.

Fiberboard products are derived by refining wood chips or chunks into fibers and gluing the fibers. Wood fibers have a relatively large length-to-cross-section ratio, meaning much of the strength of the product is derived from the fiber. As such, fiberboard products can be made for greater strength applications than particleboard. All wood can be fiberized, but softwoods are better than hardwoods for fiberboard products. High softwood content wood waste, like demolition or construction wood waste, are most appropriate for fiberization. Low-density fiberboards are used for insulation, sound deadening, and carpet underlayment. Medium-density fiberboards are often used in furniture. High-density fiberboards find their way into wood I-beam webs, furniture, and panelling substrates. In addition, wood fibers are readily molded into complex shapes; automotive interior substrates are made this way.

Flakeboard composite products, like oriented strandboard and waferboard, are manufactured by slicing flakes of wood from solid wood pieces. The wood grain can be either oriented to the flake or random, depending on the flaking operation. The cutting blades must be kept extremely sharp, so waste material must be clean and cannot contain any metals. Flakes are commonly made into sheathing products for roofs and walls. Flakeboard is also used as one or both skins in stressed skin panels and for webs in wood I-beams.

Wood-fiber–plastic composites. Using wood-based materials to reduce the cost of thermoset plastics dates to the beginning of the century. Using recycled wood or paper fiber as a reinforcing filler in thermoplastics is a recent innovation. Most commodity thermoplastics, such as low- and high-density polyethylene (LDPE, HDPE), polypropylene (pp), and polystyrene (ps), can be blended with waste wood or paper. Polyester terphalate (PET), used to make soda pop bottles, is generally not used because its melting temperature is greater than the degadation point of wood.

Using wood and paper fiber as a reinforcing filler decreases raw material cost and significantly increases rigidity and strength. The composite product made from blending waste fiber with plastic costs about one-third to one-sixth as much as pure plastic products.

The composite material does not come without trade-offs, however. Composites have lower impact resistance, but for most applications, this is not significant. Blending the wood and plastic can also be difficult. Wood and paper fiber are light and porous; plastic is dense and compact. Wood is more sensitive to moisture than to heat, while the inverse is generally true for plastics.

The recycled composite material can be recycled again and again with no significant loss of properties. The composite material can be made into products currently made with only plastic. Standard processing equipment can be used with little or no modification.

The ideal setting for producing composites is a versatile facility that can accommodate shifting availability of raw materials. Urban settings work well for this recycling technology because raw material availability and market accessibility are higher. Although commercial activity is beginning in wood–plastic composites, production has not been fully optimized. Issues related to optimizing the production of composites constitute the objectives of much of the Forest Product Laboratory research in the area of wood recycling.

Optimizing production. The first step in making wood-fiber–plastic composites is converting the waste wood or paper into a desirable form. Three issues must be considered in the conversion process: handling and feeding during blending, the ability of wood or paper to be blended into the plastic, and optimization of physical and mechanical properties. The most economical blending process must be optimized. The total cost would ideally be less than the cost of fabricating the same article from plastic alone.

Based on discussions with people in the plastics industry, researchers at the Forest Product Laboratory see an opportunity for the use of wood-fiber–plastic composites. Some manufacturers would be willing to use the composite blend in a pellet form as raw materials for producing finished goods. There appears to be a growing market for the preparation of wood-fiber–plastic composite pellets as feedstock from municipal waste.

Inorganic-bonded wood composites. Inorganic-bonded wood composites are those that contain a mineral or mineral mix as a binder system. The three most common inorganic binder systems are magnesium oxide, gypsum, and portland cement. Both magnesium oxide and gypsum are moisture sensitive, and composite products made with them are used primarily for interior applications. Portland cement-bonded products are more durable and have exterior and interior applications. All inorganic-bonded products are highly resistant to fire and insects and other pests.

There is currently one manufacturer of magnesium-oxide-bonded panel products in the United States. The product, used mostly for interior ceiling panels in commercial buildings, uses excelsior (finely shredded wood strands) as the wood component.

Gypsum products, the most common of which is drywall, have a long history of recycling. Conventional drywall is a gypsum panel that is wrapped with recycled paper. The paper wrap gives the gypsum panel much of its strength. New drywall products are coming onto the market that use waste paper material in a different manner than wrapping. Fiberized waste paper is blended within the gypsum panel. At 30% waste paper fiber, the gypsum panel is strong enough that it does not require the paper wrap. Although taping the corner seams is still recommended, it is not required on the butt seams. Gypsum, which is typically mined is also being diverted from the solid-waste stream. Flue gas gypsum is a by-product of desulfonization of flue gas coming from smoke stacks. It can be used in the manufacture of gypsum-bonded composites.

Another form of inorganic-bonded composites, cement-bonded wood composites, or as they are more commonly called, cement boards, have a long history in Europe. The Philippines, Japan, and the

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Start at the source. Successful recycling starts with proper collection and separation.

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Waste not. Construction and demolition wood waste are valuable sources of wood fiber for composite materials.

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Out of the mix. Scientists at the FPL test composite panels made from recycled wood and portland cement.

United States are just starting to use this material. Enforcement of stricter building codes may accelerate the use of cement board. For example, there may have been less damage caused by the recent fires in California if fire-resistant roofing slates and cement-bond exterior panels had been used.

Cement board is a 50/50 mixture of cement and wood or other lignocellulosic fiber. The material is surprisingly lightweight, easy to nail and saw, and has excellent insulation properties. In addition, cement board is very resistant to moisture, rot, and insect and vermin attack. Wood can also be used as the aggregate in cement to make lightweight building blocks.

Cement-bonded wood composites are used in a wide range of building types. In the Philippines, cement board is fabricated using mostly manual labor and is used in low-cost housing. In Japan, the fabrication of cement board is automated and used in expensive modular housing. The versatility of cement board manufacturing makes it ideally suited to recycled wood. With a small capital investment and the most rudimentary tools, good-quality cement boards can be produced on a small scale using generally unskilled labor. If the market for cement board increases, technology can be introduced to increase manufacturing throughput. The labor force can be trained concurrently with the gradual introduction of more sophisticated technology.

The United States has one commercial manufacturer of cement-bonded panel products. These panels are used in many of the same applications as magnesium-oxide-bonded panels. Other U.S. manufacturers are starting to open the market for cement-bonded panels with roofing slates and exterior siding. These products, at one time made using asbestos as fiber reinforcement, now use recycled paper fiber or paper mill sludge as a fiber source. These products are long lasting and durable, some have a 60-year warranty.

The Forest Product Laboratory has been working with cement board for several years and believes there are great market opportunities for this building material in the United States. One research project examined the use of carbon dioxide in curing cement. The introduction of carbon dioxide into the composite dramatically accelerates curing. Initial cure time can be reduced from more than 12 hours to less than 5 minutes. This technology is adaptable to board, panel, and block products.

One size reduction technique that has a good chance for successful application in cement board is wood splintering. Splinters are made by crushing wood between two serrated rollers. Wood waste is fed into the gap between the rollers with its grain parallel to the axis of the rollers. The rollers run at different speeds, tearing the wood apart and crushing it into splinters. Splinters are especially attractive for use in recycled wood products because no cutting is required, eliminating the need to sharpen blades that may be damaged by metals. Splinters also have high length-to-cross-section ratios; splinters are strong and can be highly oriented. Inorganic-bonded panels have already been made at Forest Product Laboratory that use splinter technology. In the panels, splinters were oriented to make a three-layer board. The faces were made of small splinters aligned 90° to the coarse splinter core.

Consumption Closes the Recycling Loop

What will it take to make waste wood recycling happen? First and foremost, profits must be made. For comparison, briefly look at the economics of plastic recycling. Currently, the cost for recycled plastic resin is about the same, or in some cases slightly greater, than virgin plastic resin prices. This is because the cost of collecting, separating, cleaning, and processing the recycled resin is close to the cost of buying crude oil and converting it into plastic. The plastics business is quick to point out that for plastic recycling to be really profitable, crude oil prices need to increase considerably. Given the supplies of available crude oil, this is unlikely to happen in the near future.

Similarly, waste wood is abundant. To be incorporated into recycled products, waste wood from ordinary consumers must compete with that from industry and with virgin wood. The latter two supplies of wood are much more uniform, consistent, and predictable in content. With supply of waste wood greatly exceeding demand, commercial users can be very selective. Although most of these large-volume users of waste wood get their material free, some are charged a fee that is nevertheless below the going landfill rates. This "avoided cost" saves the disposer money and helps the large-volume user with processing costs.

One way to advance recycling is by local, state, and federal government mandates and by purchasing products with minimum recycled content. Mandates operate on the principle that the public benefit is greater than any potential economic cost. Increased costs would most likely be realized by increased product prices (profit for industry) or by other financial support for recycling, such as subsidies or credits. These costs may not always be obvious. For example, the cost for a carpenter to separate building materials at the job site could be passed to the consumer in the form of high building prices. The office worker separating paper types is probably earning many times more in wages than the value of the paper. This could be viewed as adversely affecting productivity.

Ideally, products and technologies will be developed so that the use of municipal waste as wood composites or other products will occur with no additional, and perhaps even reduced, cost to the consumer. If higher costs are necessary, the consumer will have to compare the advantages of the product to their personal values. Ultimately, consumers vote with their pocketbooks.

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Suggested Reading

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